Thesis Report
On
"Navigation of Mobile Robot using Fuzzy Logic"

Bachelors of Technology
In
Mechanical Engineering

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Contents

DEPARTMENT OF MECHANICAL ENGINEERING

CERTIFICATE

This is to certify that the thesis entitled **"Navigation of Mobil Robot using Fuzzy Logic**" is the bona fide work of *Krushna Shankar Sethi and SanjeevPothen Jacob* under the Guidance of **Dr. D.R.K.Parhi** for the requirement of the award of the degree of **BACHELOR OF TECHNOLOGY** specialization **"Mechanical Engineering"** andsubmitted in the **Department of Mechanical** Engineeringat **National Institute of Technology Rourkela**, During the period 2012-2013.

Dr. D.R.K Parhi
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ACKNOWLEDGEMENT

I wish to express my sincere gratitude to **Dr. D.R.K. Parhi** for his inspiring encouragement Guidance and efforts taken throughout the entire course of this work. His constructive Criticism, timely help, and efforts made it possible to present the work contained in this Thesis.

I am grateful to Prof. S.K. Sarangi, Director, and Prof K.P Maity, Head of the Department, Mechanical Engineering, for their active interest and support.

I am also thankful to the PHD students of Mechanical Engineering Department, National Institute of Technology, Rourkela for providing all kind of possible help throughout the Completion of this work.

I express my deep sense of gratitude and reverence to my beloved parents for their blessings, Patience and endeavor to keep my moral high at all times. Last but not the least; I wish to express my sincere thanks to all those who directly or indirectly helped me at various stages of this work.

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Abstract

In this paper research has been carried out to develop a navigation technique for an autonomous robot to work in a real world environment, which should be capable of identifying and avoiding obstacles, specifically in a very busy a demanding environment. In this paper better technique is develop in navigating mobile robot in above mention environment. The action and reaction of the robot is addressed by fuzzy logic control system. The input fuzzy members are turn angle between the robot head and the target, distance of the obstacles present all around the robot (left, right, and front, back).The above mention input members are senses by series of infrared sensors. The presented FLC for navigation of robot has been applied in all complex and adverse environment. The results are hold good for all the above mention conditions.

Key words: navigation, real world environment, fuzzy logic, mobile robot.

INTRODUCTION

Since time immemorial there has been a constant effort to build and construct a **conscious machine (robot)** that should be capable of thinking like human beings, for this there is a tremendous craze among the modern thinkers, philosophers and researchers. Here we are mainly focusing on robotics and its potential utility in engineering, medical, industries, mines biomedical science and many more. So what is there in robotics that has attracted thousands of scholars from various backgrounds and most probably each of them having different requirements .This is because robots can work as conscious as that of a human being ,more over it work with such a precision that left human being with wonder struck. Robots need very less human involvements this is another big advantages of adopting robotics in real life. Now, we are moving towards autonomous mobile robot, i.e.,it should be capable of doing things in an undefined and unmodified environment and without human interventions. In simple words it should be capable of acting in a real world environment. A well to do autonomous robot should be capable of doing many things like,

- With no difficulty it should be able collect information about the surrounding.
- It must travel from one destination to another with no human assistance.
- Must avoid obstacle in its path.
- If necessary act according to the situations.

Now the prime focus is how to develop techniques for autonomous mobile robot navigation. Developing navigational techniques has attracted many researchers, students and become one of the major trends in navigational robotics. . This trend is highly motivated by the current thin gap between the available technology and the new user application demands .One of the major problem in industrial robotics is that lack of flexibility, autonomy, frequent breakdown: usually, these robots only perform pre-programmed or pre-defined sequences of operations in highly constrained environments, and are not able to operate in partially new or completely environments or to face unexpected situations. In these conditions they are no better than dead matter. Now in the current market scenario there is a heavy competition for complete autonomous robots. There are so many soft computing techniques used for mobile robot navigation such as neural network and genetic algorithm, particle swarm optimization and are also considered to be the best way for expressing the subjective uncertainties in human mind. Now question arises although there is lot of techniques in navigation of mobile robots then, why we are opting for, especially, fuzzy logic control system. If navigation is of so much interest then what is navigation? How it works? To answer these questions we have to think very carefully; navigation is the process of determining and maintaining a specific path that is free of obstacles and optimized one and leads to the final destination. Fuzzy logic control system provides a wonderful platform in which human perception-based action can be easily performed. Using the fuzzy logic control system, the way human being thinks and make decision can be formulated and implemented in robotics by simple IF–ELSE rules and can be combine with easily understandable and natural linguistic representations. Localization map and cognition path planning are the two most vital sub systems for the fuzzy interface technique. These two subsystem are incorporated and utilized in the fuzzy logic control system as fuzzy rule sets. The input to the fuzzy system is the perception information by the sensors about the environment and the output is in terms of motion control of the robot: slow, fast, left turn, right turn, straight motion and heading angle.

The prime goal of this paper on fuzzy logic control system is to bring reactive navigation techniques is to allow autonomous units, so that with relatively low-cost sensors and actuators, to perform difficult tasks in a completely unstructured or unknown environments. Fuzzy Logic control techniques have a wide range of potential application fields, this include the exploration in to the completely inaccessible or hazardous environments, industrial automation, biochemistry and also biomedicine. In this research, the development of Fuzzy Logic Control system for decision and control strategies necessary for autonomous control of mobile robots plays a vital role.

2. Literature review

Fuzzy logic is a mathematical formulation that provides information about the uncertainty in a given unstructured environment, was established in [1].Demirli and Turks, [2]describe about a technique which based on fuzzy model of sonar sensor which gets its data from experiment and compare the dryness and wetness of a particular surface. Zhou, Meng[3]worked on how to improve the biped gait using a special technique called FRL agent with fuzzy evaluative responses.

Parhi [4] have describe about the development of control technique for an autonomous mobile robot to navigate in a real world environment,it should be capable of avoiding obstacle in its path it may be structured or unstructured, in a busy and unpredictably changing environment. Navigation means control of a machine from its starting point to its ending point in a particular area following a path that is comprises of either a curve or a series of jointed curve segments[5] and also develops a navigation technique called as "functional or horizontal decomposition." Pratiharand Bibel [7] have developed an obstacle avoidance technique,i.e., for collision-free path for multiple robots using genetic-fuzzy systems. Pradhan et al. [6, 8] have used potential field approachto navigate mobile robots. They have shown their results in simulation and the results are in accord with the assumptions made.Fraichard and Garnier [9] have presented motion control architecture technique for a car or it may be any kind of four wheeler vehicle which is specifically intended to move in a dynamic and partially known environments. They have used fuzzy logic technique, which mainly comprises of a set of fuzzy rules encoding the reactive behavior of the vehicle. They have successfully navigated the car-like vehicle with use of fuzzy logic control approach. In case of robot soccer, fuzzy logic is very much essential, fuzzy logic has been used in many occasion but it is specially implemented in individual robot behaviors and actions, in particular for shooting and obstacle avoidance [13], [12]. Hierarchical fuzzy control is utilized in behavior-based architecture [11], and fuzzy logic in game strategy selection [10].In the above case an extensive fuzzy behavior-based architecture is proposed and implemented on a robot soccer system. The fuzzy behavior-based control architecture is exclusively used for manage a team of soccer robots, by fragmenting the entire team into different roles, each role into different perception based behaviors, and then behaviors into actions. The robot soccer system provides a highly unstructured and dynamic environment for the multiple mobile robots to operate in an unknown environment. Basically it is based on a multiagent environment where robots need to cooperate or compete with one another or with the opposite team to achieve certain tasks. All the results are well accordance with the expectations and it is highly evolved fuzzy logic control in case of mobile robot navigation .In another case different attributes like steering angle ,obstacle distance ,speed are considered as fuzzy logic behaviors, and fuzzy logic control system is implemented to achieve various desire behavior to achieve the goal of target seeking in [14].Here fuzzy control is adopted to coordinate the different system behavior in response to the environment. It is based on the fact that a fuzzy system is sub-divided in to small fuzzy control system instead of having a large centralize fuzzy control system. It works on the basis of perception based action. Fuzzy control is characterized by the use of linguistic rules to manipulate and implement human knowledge in control systems so as to handle the uncertainty present in the environment [15].Levitt and Lawton [16] defined the aim of navigation control as providing answers to the following questions:

- Current position of the robot?
- Position of the others with respect to the robot?
- How to reach to other places from the current position.
- How to decide a collision free path?
- Whether it is able to locate obstacle or not?
- Path followed is optimized or not?

To address both issues a mobile robot must have a way to perceive its environment. And lot of effort is given on the above core questions in robotics.

3. Developing a fuzzy interface for obstacle avoidance

Fuzzy logic is extensively used in mobile robot navigation. In fuzzy logic, fuzzy logic controllers include different heuristics control mechanisms in different form e.g. if-then, else-if etc. rules which help to build an efficient robot having different humanly like qualitative and quantitative functionality with control flow mechanisms. Controller should be as intelligent as human or in a better way to avoid interrupts which occurs while performing activities to reach to the destination. There may be different types of obstacles on the path and hence it should provide an efficient mechanism to categorize the obstacles and take action accordingly. The modeling of various types of impression and uncertainty is allowed by fuzzy logic and hence it allows to numerate computation and to integrate symbolic reasoning in a natural framework of the system.

There are different flow controls in fuzzy logic control system and is shown in the fig-1.The first step in this control process is the fuzzy controller will study the environment under which it is kept, and this is to be accomplished by a number of infrared sensors. After this the information will be convey to the fuzzy logic control system through the information extraction system. Now The prime decision has to be taken by the fuzzy logic controller for obstacle avoidance and path mapping. This information has to be passed to the robot using certain type of circuit. The robot will follow a particular path according to the information given by the fuzzy logic controller. Now it's the time for obstacle avoidance, the motion of the robot is completely perception based action, if he noticed any obstacle in its path then he have to follow a collision free path which is decided by the fuzzy logic controller. Now this has to be followed till the robot reaches to its destination. The complete flow chart is shown in fig-1

According to the information acquired by the sensors, the reactive behaviors are decided by the fuzzy logic controller system/fuzzy logic algorithm to maintain the speed the velocity of the two driving wheels of the proposed mobile robot. The proposed fuzzy system consists of four components: fuzzification, fuzzy rule, fuzzy interface, and defuzzification. The inputs for the fuzzifier are the information gain by the sensors; now this information is also input to the fuzzy set defined in; the defined fuzzy set is characterize by different fuzzy member function like near, medium, far, left_obs, right_obs, front_obs, head_ang and the control parameters slow, med, and fast.

These member function are used for fuzzify the velocity of the robot wheels say left_vel and right_vel respectively, this particular thing is adopted from [4].

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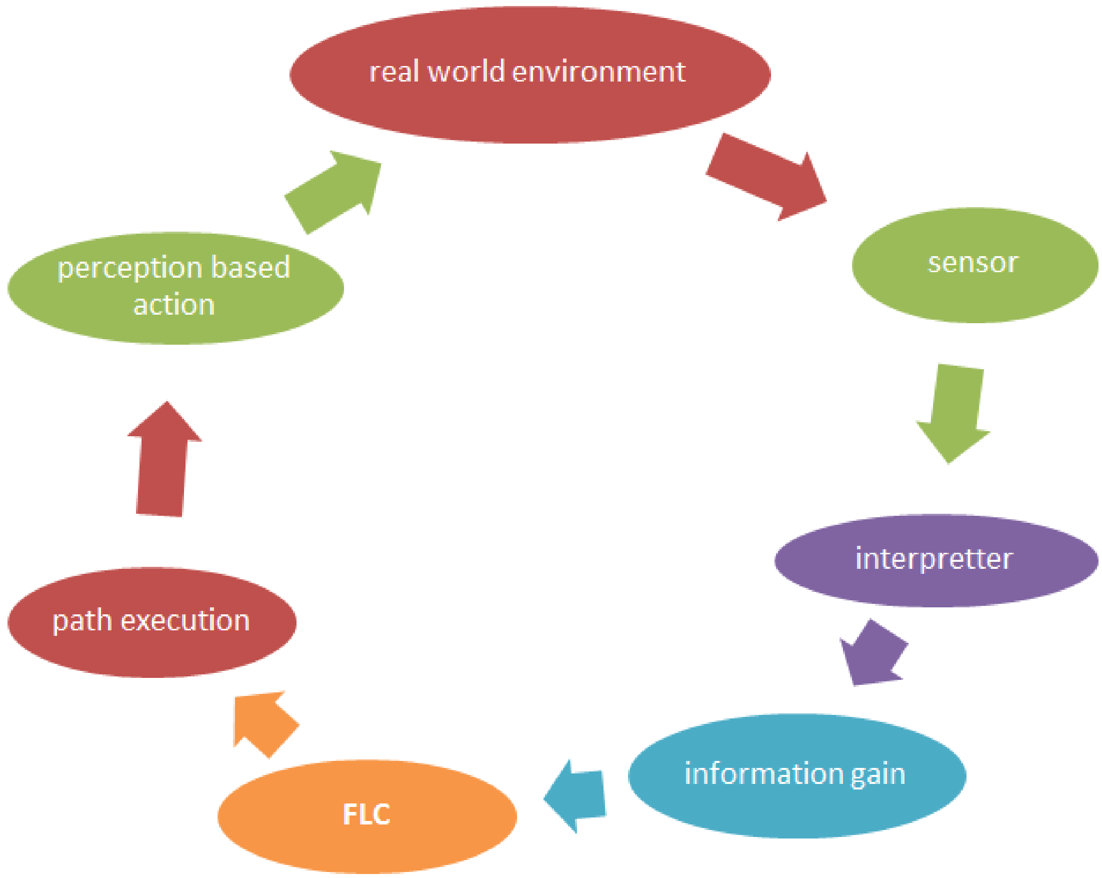


Fig-1: flow chart showing the step involved in fuzzy logic control.

The robot for which this fuzzy logic control system is develop is consider to be a rear wheel drive consisting of two rear wheel namely right and left rear wheel. The robot has got some series of infrared sensors for measuring distance of obstacles as well as destination around it and identifying the target. The parameters with which we are concern are front obstacle distance (F_OBS_D), left obstacle distance (L_OBS_D), right obstacle distance (R_OBS_D), and finding the heading angle (H_ANG). The distance between the obstacle and the robot is consider to be safe up to a certain distance after which it started deviating from the original path this can be consider as a kind of repulsive force acting between two bodies and the distance between the target, and the robot is consider to be that of an attractive force ,which results in reaching to the final destination.

In this particular paper we are incorporating three kinds of member functions. They are Trapezoidal, Triangular and each having few parameters. The complete list is given below.

INPUT MEMBER FUNCTION

Fuzzy set	***Member Functions***	***Parameters***
1. Left_obs	2 Trapezoidal	Near, Far
	1 Triangular	Medium
2. Right_obs	2 Trapezoidal	Near, Far
	1 Triangular	Medium
3. Front_obs	2 Trapezoidal	Near, Far
	1 Triangular	Medium
4. H_ang	2 Trapezoidal	Positive, Negative
	1 Triangular	Straight

OUTPUT MEMBER FUNCTION

5. Left_vel	2 Trapezoidal	Slow, Med
	1 Triangular	Fast
6. Right_vel	2 Trapezoidal	Slow, Med
	1 Triangular	Fast

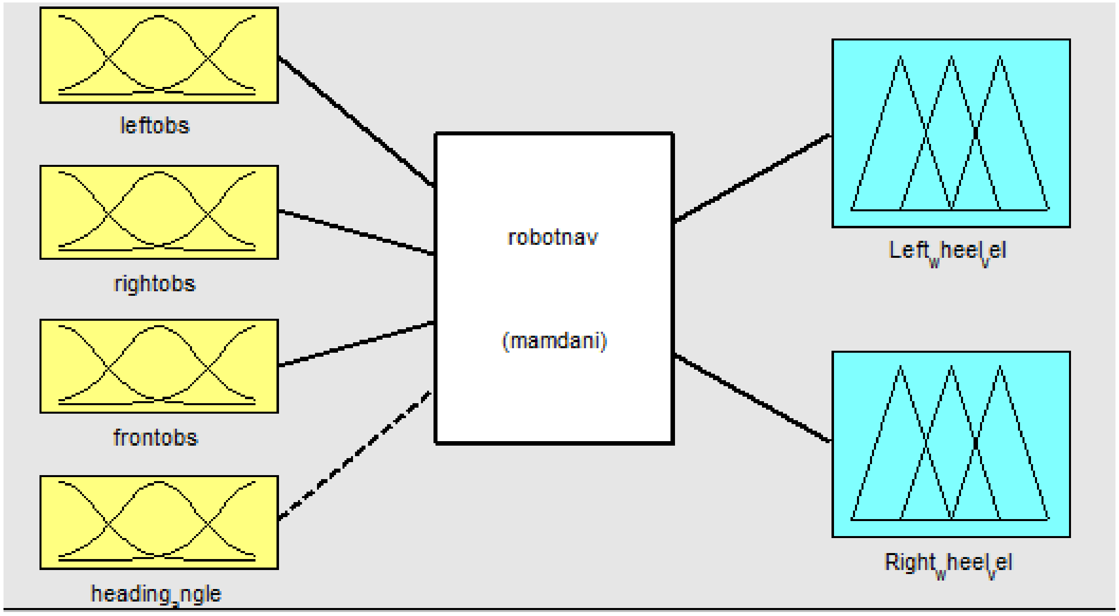


Fig2-fuzzy logic logic input and output member functions.

Now going details in to fuzzy membership functions each member function is characterise be different control parameters,e.g, consider one input member function called “leftobs”;here the parameters that we are considering are:distance of obstacle from the robot to its left,right,and front.If the obstacle is at a distance limit of 0-0.6m it is assign as near, 0.6-0.9 it assign as medium,0.9-1.0 it assign as far.The same is applicable to “rightobs”,”frontobs”.Simillarly the “heading angle”membership function is defined.Below are the shownmember functions and its different parameters.

Different input and output fuzzy set is shown along with their member function

Input member functions

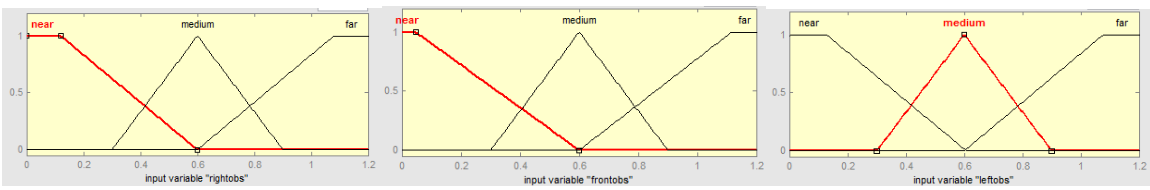
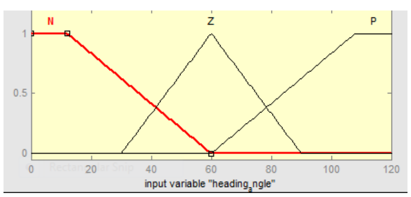


Fig-3: Input member functions

Left obstacle **Right obstacle** **Front obstacle**



Heading angle

Output member function

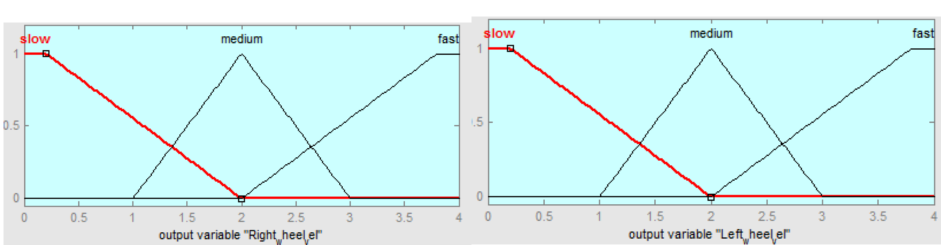


Fig-4: Output member function

Right wheel velocity **Left wheel velocity**

Now we are concern about the navigation of robot with obstacles.As the obstacle will come closer to the robot say to its left,right, and front the velocity of the left wheel and right wheel will very accordingly.This can be demonstraed by the following way

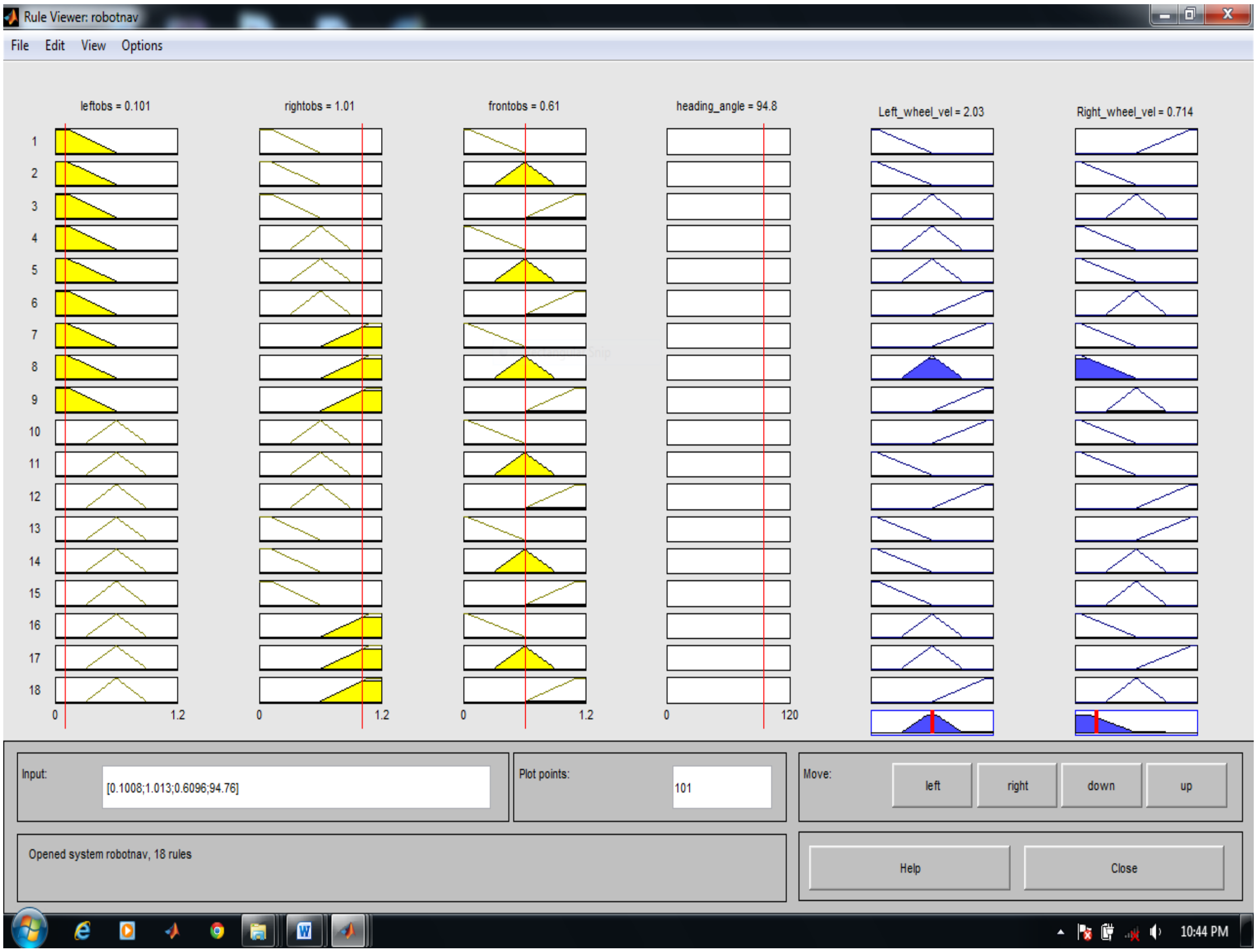


Fig 5: output in fuzzy interface

For this particular rule editor output are given below

Left obstacle distance = 0.101 unit
Right obstacle distance= 1.01
Front obstacle distance= 0.61
Heading angle = 94.8
Output
Left wheel velocity= 2.03
Right wheel velocity= 0.714

Another output is given below

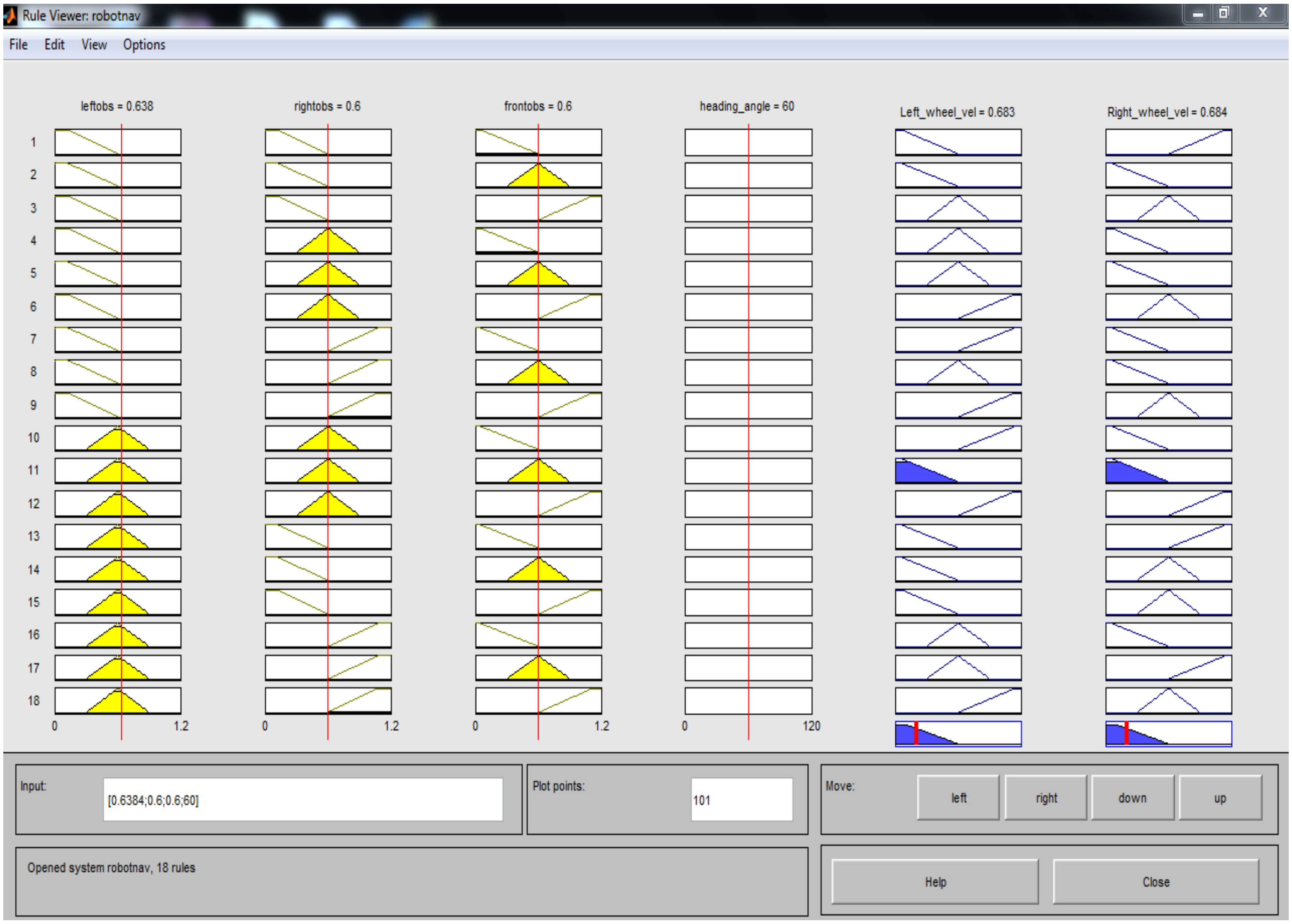


Fig 6-Schematic diagram of fuzzy logic for navigation of mobile robots

Output-2

Left obstacle distance = 0.638 unit
Right obstacle distance= 0.6
Front obstacle distance= 0.6
Heading angle = 60

Output
Left wheel velocity= 0.683
Right wheel velocity= 0.684

Rules that are used in fuzzy logic control system are given below in tabular form.

Table-1.

Rule no	operator	Left_obs	operator	Right_obs	operator	Front_obs	operator	Head_ang	Operator	Left_vel	Right_vel
1	If	Near	And	Near	And	Near	And	Any	Then	Slow	Fast
2	If	Near	And	Near	And	Medium	And	Any	Then	Slow	Slow
3	If	Near	And	Near	And	Far	And	Any	Then	Med	Med
4	If	Near	And	Medium	And	Near	And	Any	Then	Med	Slow
5	If	Near	And	Medium	And	Medium	And	Any	Then	Med	Slow
6	If	Near	And	Medium	And	Far	And	Any	Then	Fast	Med
7	If	Near	And	Far	And	Near	And	Any	Then	Fast	Slow
8	If	Near	And	Far	And	Medium	And	Any	Then	Med	Slow
9	If	Near	And	Far	And	Far	And	Any	Then	Fast	Med
10	If	Medium	And	Medium	And	Near	And	Any	Then	Fast	Slow
11	If	Medium	And	Medium	And	Medium	And	Any	Then	Slow	Slow
12	If	Medium	And	Medium	And	far	And	Any	Then	Fast	Fast
13	If	Medium	And	Near	And	Near	And	Any	Then	Slow	Fast
14	If	Medium	And	Near	And	Medium	And	Any	Then	Slow	Med
15	If	Medium	And	Near	And	Far	And	Any	Then	Slow	Med
16	If	Medium	And	Far	And	Near	And	Any	Then	Med	Slow
17	If	Medium	And	Far	And	Medium	And	Any	Then	Med	Fast
18	If	Medium	And	Far	And	Far	And	Any	Then	Fast	Med
19	If	Far	And	Near	And	Near	And	Any	Then	Slow	Med
20	If	Far	And	Near	And	Medium	And	Any	Then	Med	Fast
21	If	Far	And	Near	And	Far	And	Any	Then	Med	Fast
22	If	Far	And	Medium	And	Near	And	Any	Then	Slow	Fast
23	If	Far	And	Medium	And	Medium	And	Any	Then	Slow	Med
24	If	Far	And	Medium	And	Far	And	Any	Then	Med	Fast
25	If	Far	And	Far	And	Near	And	Any	Then	Fast	Slow
26	If	Far	And	Far	And	Medium	And	Any	Then	Fast	Med

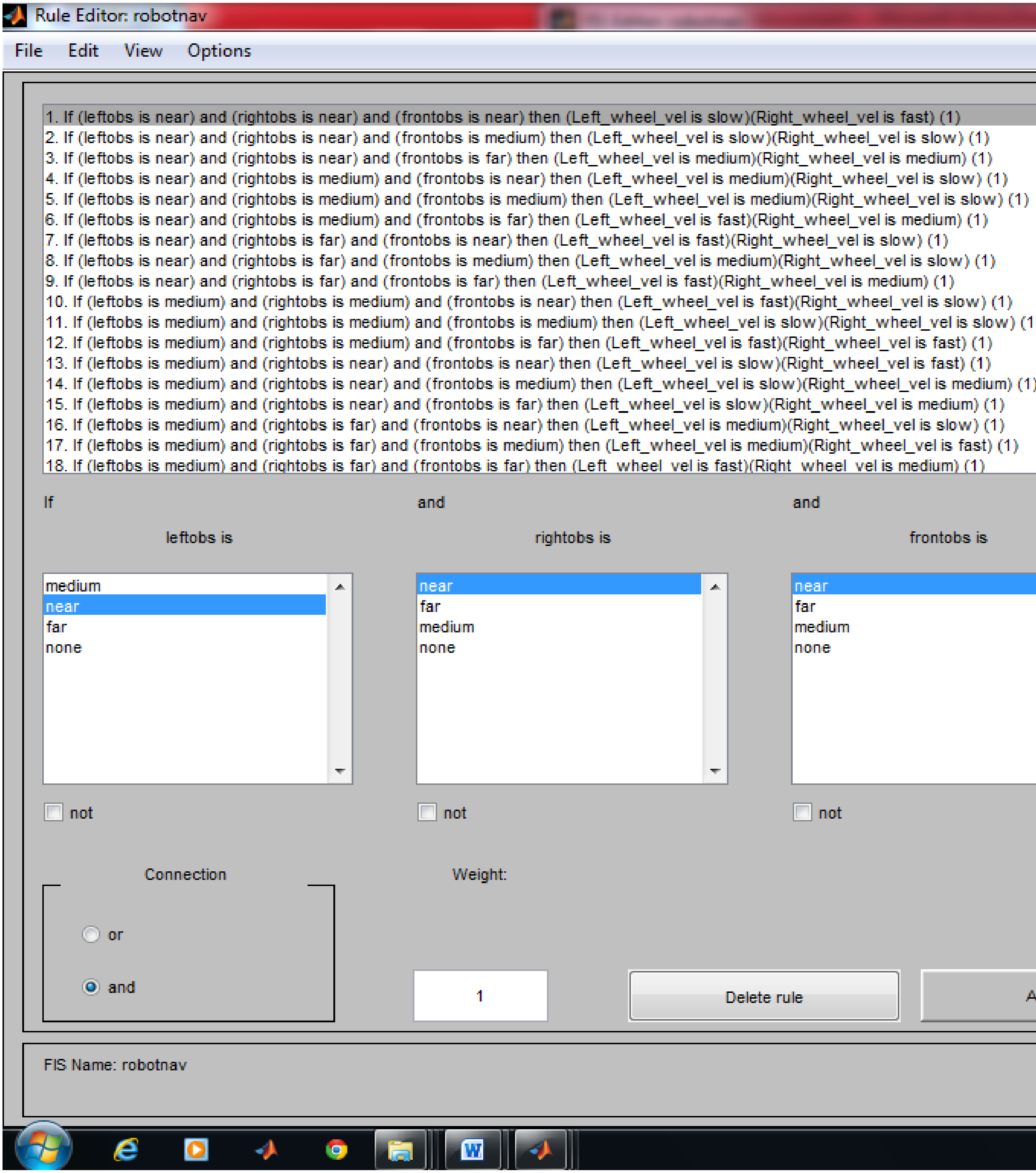


FIG 7- RULES FOR MOBILE ROBOT NAVIGATION

Obstacle Avoidance

Obstacle avoidance is one of the most important feature of mobile robot navigation without which it is like good for nothing. When the robot is very much close enough to collide with the obstacle , it must change its path ,speed and heading angle in order to reach the destination with a collision free path that is why obstacle avoidance is of so much important. The fuzzy rules that are incorporated during the obstacle avoidance is given in a tabular form. Specially, when the robot is very much close to the obstacle it must slow down and change its steering angle and this particular principle is used for any kind of curvilinear track or path. All the rules that we have used during the fuzzy logic controller design is given in a tabular form.

Few rules are shown for our better clarification

If (Left_obs_dis is near and Right_obs_dis is near and Front_obs_dis is near and H_angia any) then (Left_whe_vel is slow and Right_whe_vel is fast).

If (Left_obs_dis is far and Right_obs_dis is far and Front_obs_dis is near and H_angia any) then (Left_whe_vel is slow and Right_whe_vel is fast).

Here an obstacle avoidance situation is shown.

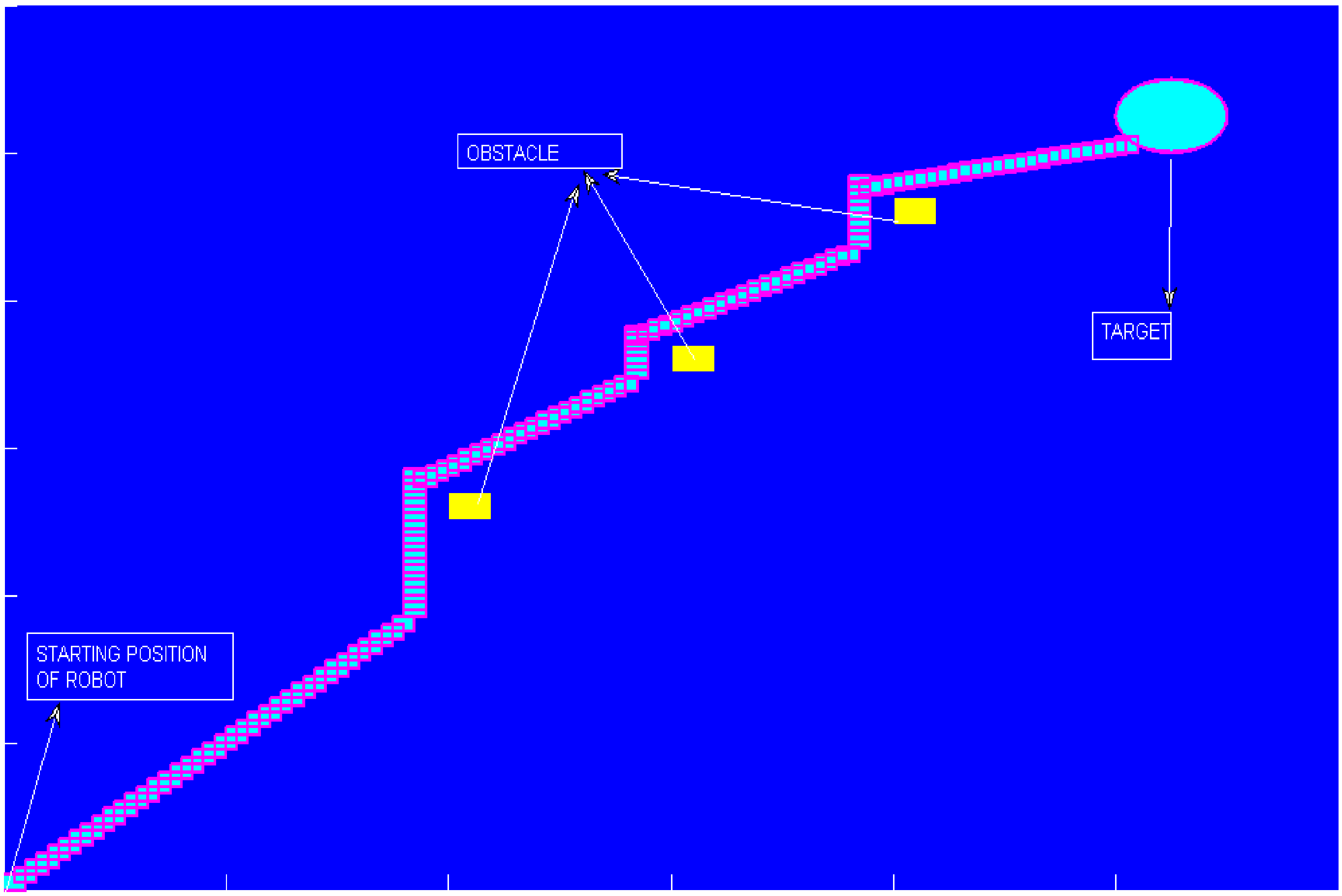


Fig 8- obstacle avoidance

This particular case is for single robot and single destination.

Obstacle avoidance for double robot and single destination.

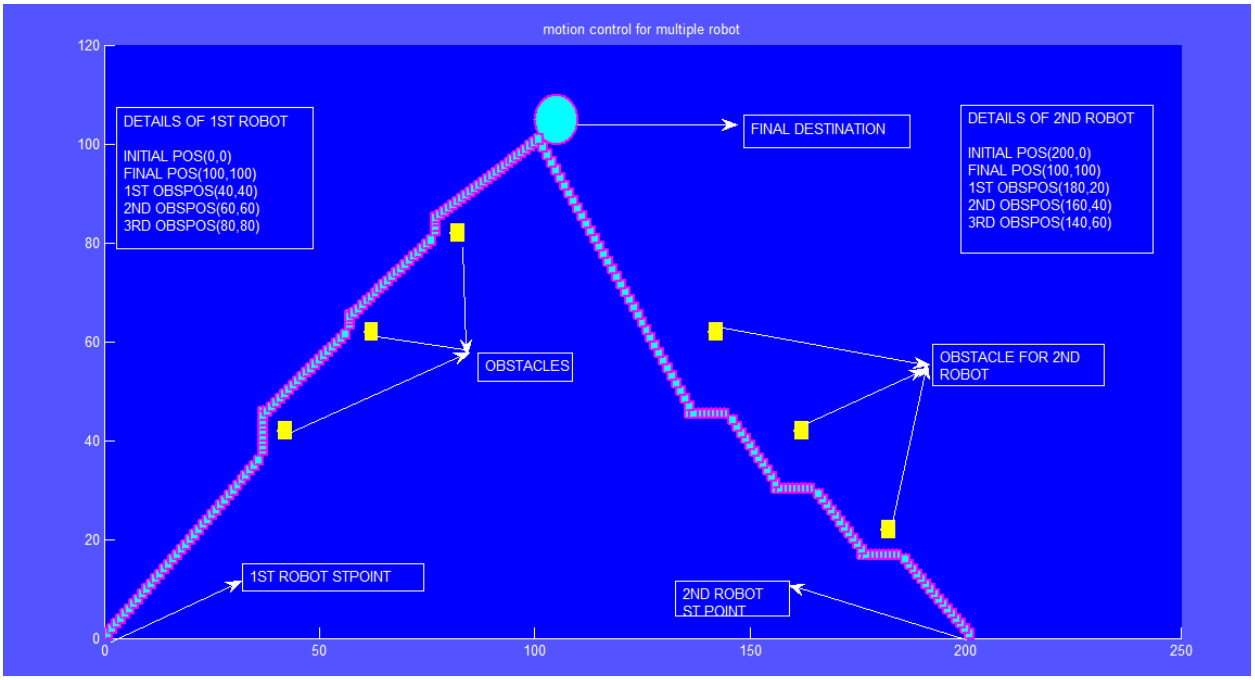


Fig 9- Obstacle avoidance for double robot and single destination

Obstacle avoidance for double robot and double destination

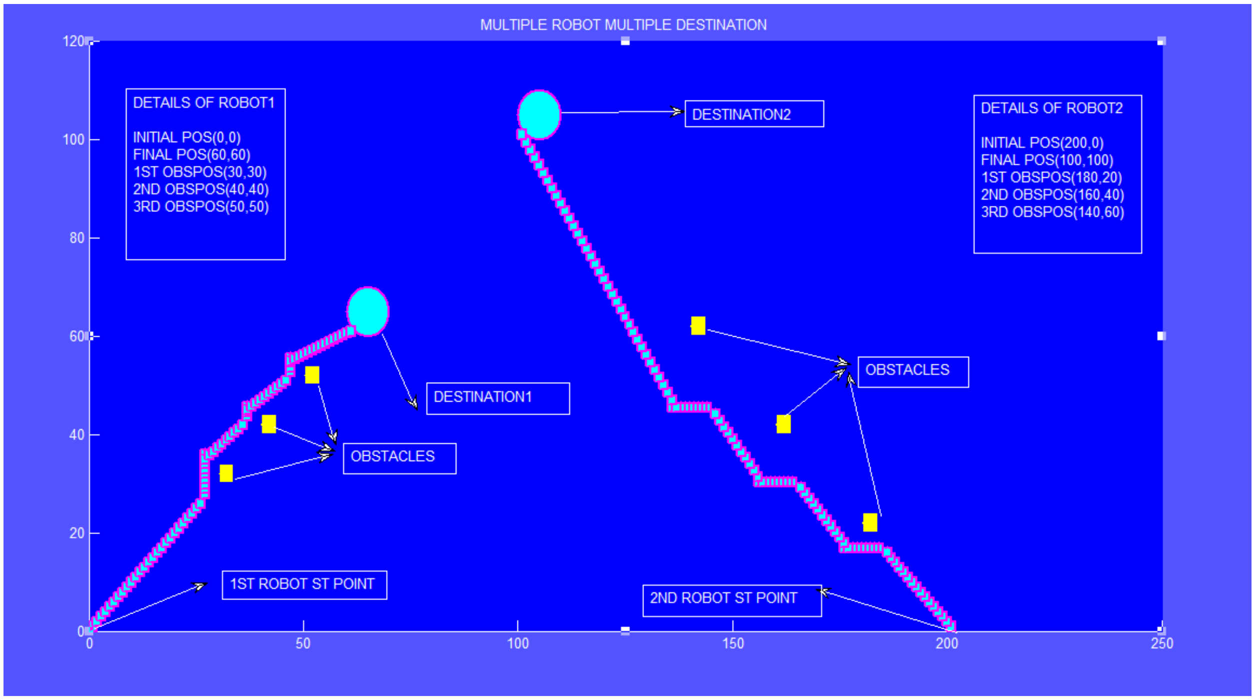


Fig 10- Obstacle avoidance for double robot and double destination

ANALYSIS AND RESULT:

Here we are doing two type of analysis
1.velocity analysis
2.obstacle avoidance analysis.

1.Velocity analysis:

In this case we are checking whether the left wheel vlocity and right wheel velocity is changing or not according to our desire or it fails somewhere.For this here we are presenting a set of datas that shows that the velocity change of left wheel and right wheel is inaccordance with our requirements.

Result of velocity control

Table-2

Left obstacle(mt)	**Right obstacle (mt)**	**Front obstacle (mt)**	**Heading angle (degree)**	**Left wheel vel (m/sec)**	**Right wheel vel (m/sec)**
0.12	**0.84**	**0.418**	**any**	**2.55**	**0.826**
0.302	**0.715**	**0.418**	**any**	**2.42**	**0.876**
0.456	**0.715**	**0.418**	**any**	**1.92**	**3.74**
0.926	**0.715**	**0.418**	**any**	**2**	**2**
0.13	**0.293**	**0.187**	**any**	**0.74**	**3.26**
0.13	**0.466**	**0.187**	**any**	**1.58**	**1.64**
0.13	**0.907**	**0.187**	**any**	**3.26**	**0.74**

2.Obstacle avoidance analysis:

In this case we are placing the obstacle in different places and checking whether the robot is reaching the destination with out collision or not. Here we are considering four CRITICAL POSITION through which robot has to pass and reach the destination.

Below are the four critical situations.

CRITICAL POS-1

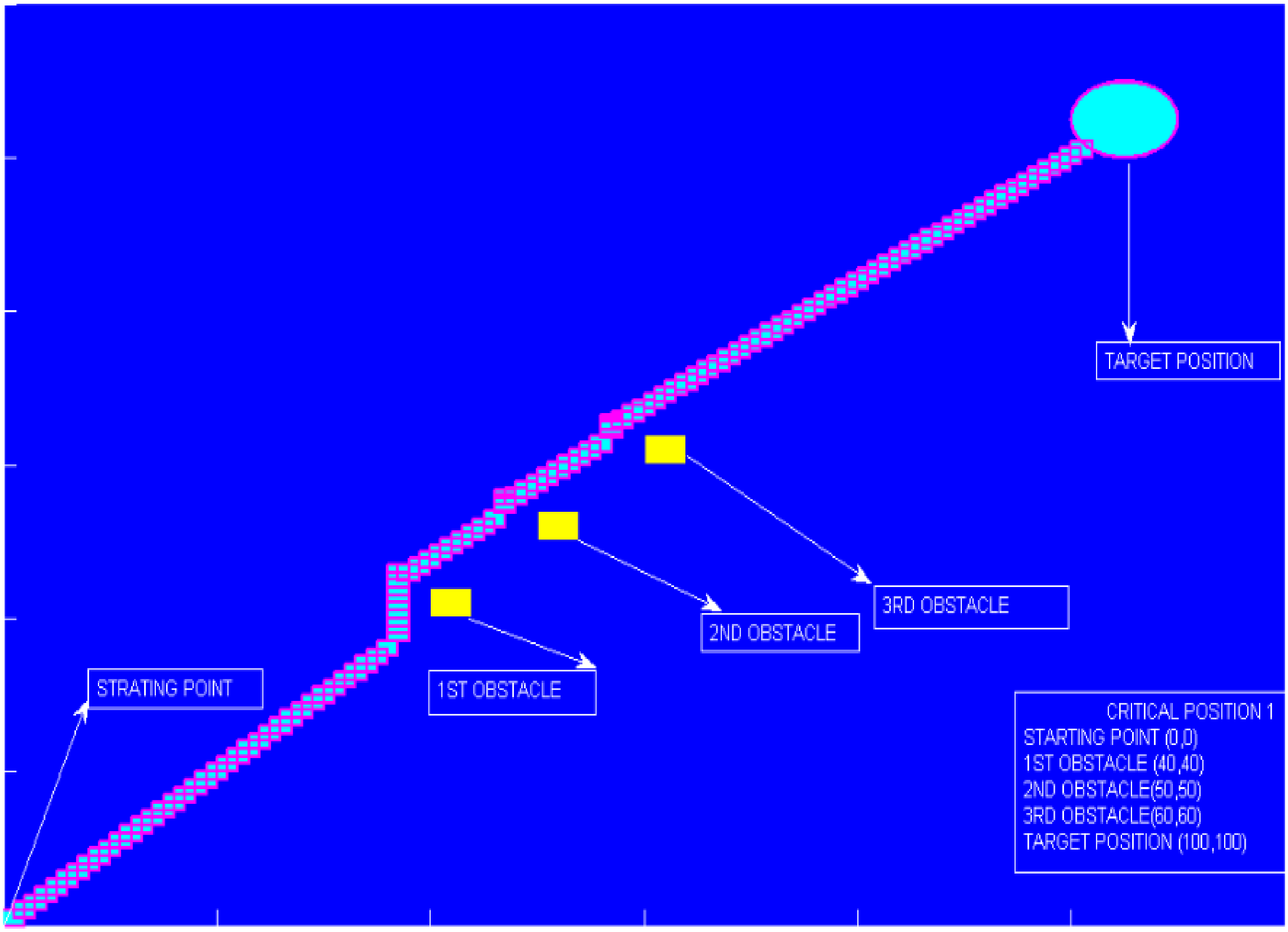


Fig 11- Obstacle avoidance for single robot and single destination case1

Input data

enter the target co-rdinate in x-axis =100

enter the target co-ordinate in y-axis =100

enter the obstacle in x-axis =40

enter the obstacle in y-axis =40

enter the obstacle in x-axis =50

enter the obstacle in y-axis =50

enter the obstacle in x-axis =60

enter the obstacle in y-axis =60

CRITICAL POS-2

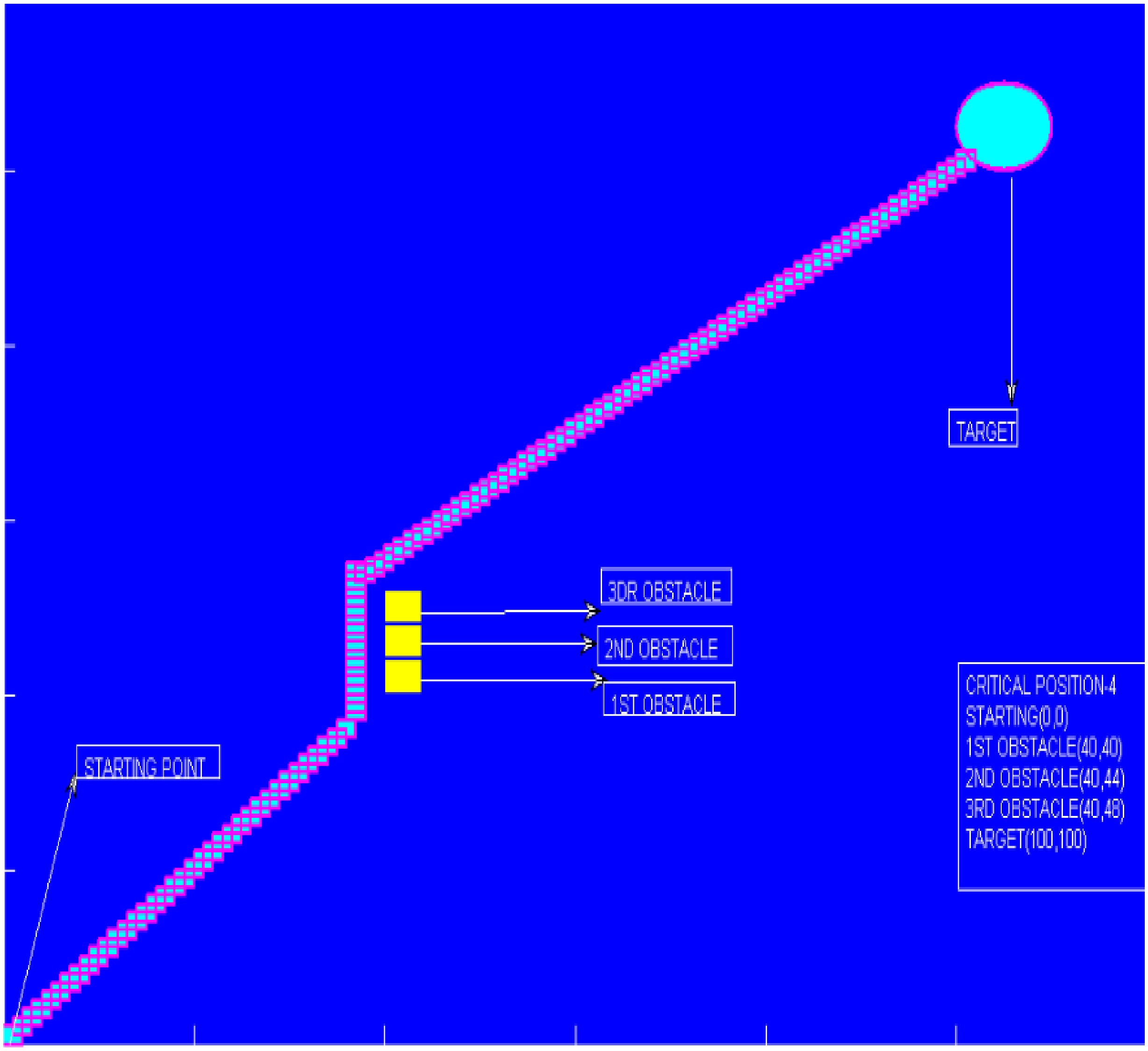


Fig 12- Obstacle avoidance for single robot and single destination case2

enter the target co-rdinate in x-axis =100

enter the target co-ordinate in y-axis =100

enter the obstacle in x-axis =40

enter the obstacle in y-axis =40

enter the obstacle in x-axis =40

enter the obstacle in y-axis =44

enter the obstacle in x-axis =40

enter the obstacle in y-axis =48

CRITICAL POS-3

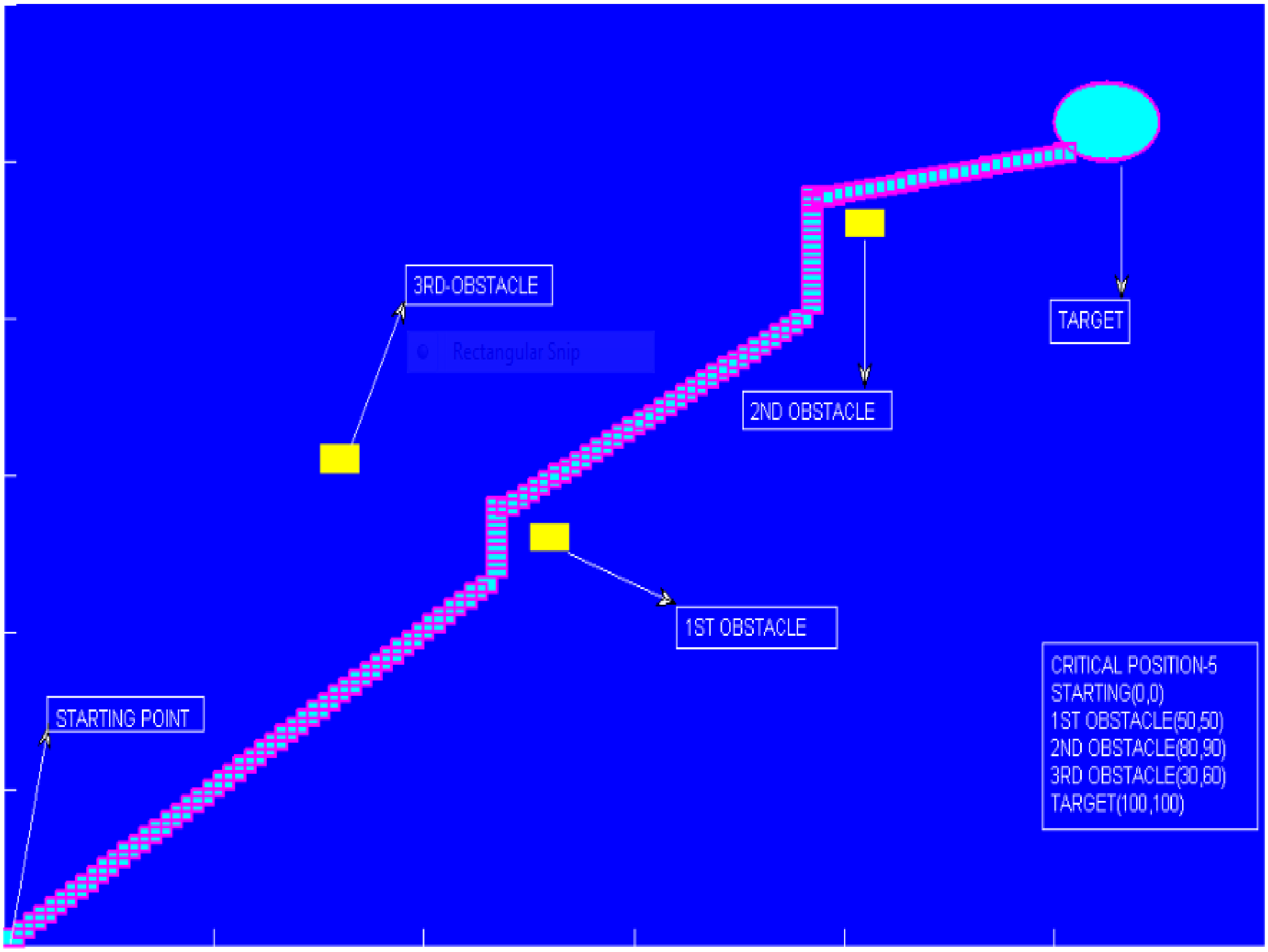


Fig 13- Obstacle avoidance for single robot and single destination case3

enter the target co-rdinate in x-axis =100

enter the target co-ordinate in y-axis =100

enter the obstacle in x-axis =50

enter the obstacle in y-axis =50

enter the obstacle in x-axis =80

enter the obstacle in y-axis =90

enter the obstacle in x-axis =30

enter the obstacle in y-axis =60

CRITICALPOS-4

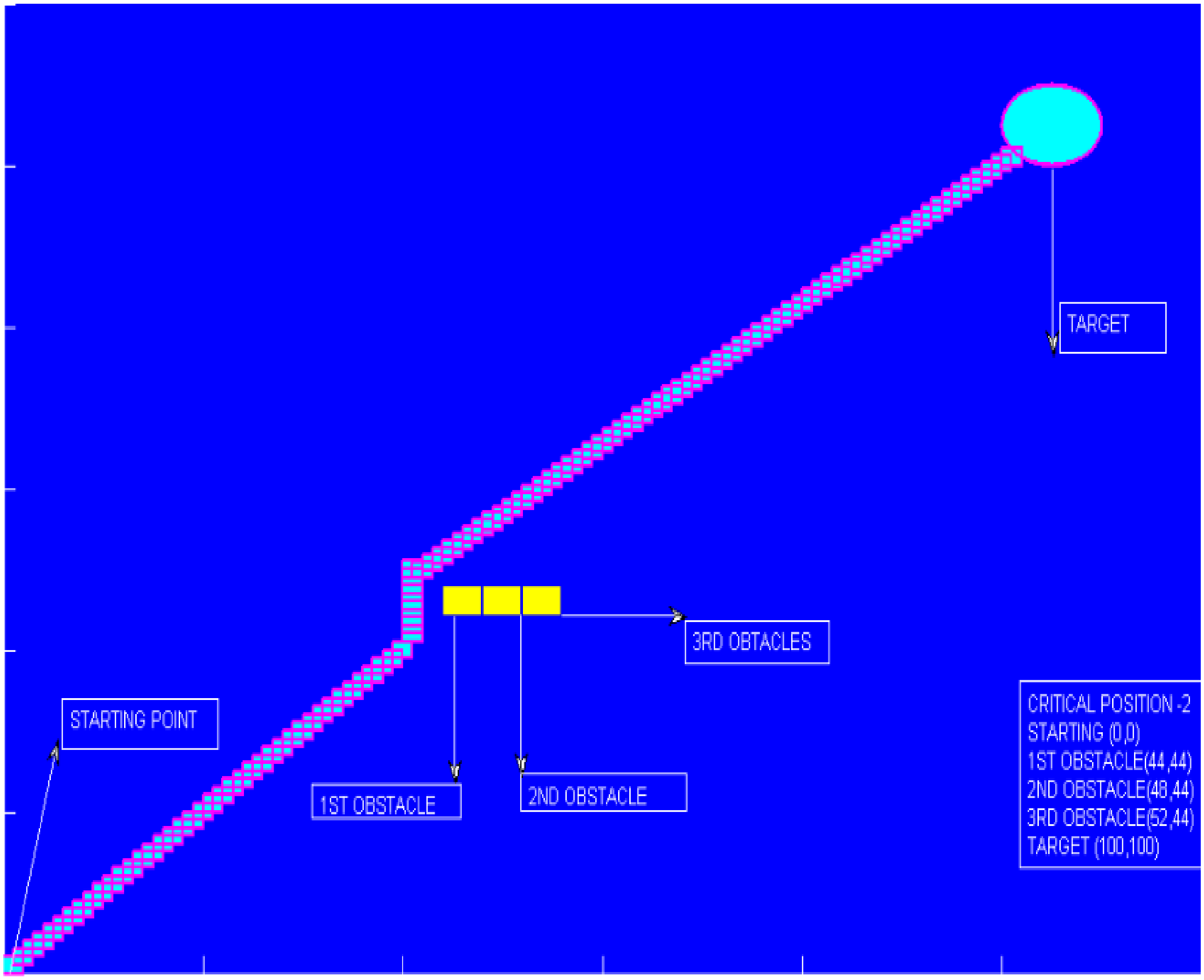


Fig 14- Obstacle avoidance for single robot and single destination case4

enter the target co-rdinate in x-axis =100

enter the target co-ordinate in y-axis =100

enter the obstacle in x-axis =44

enter the obstacle in y-axis =44

enter the obstacle in x-axis =48

enter the obstacle in y-axis =44

enter the obstacle in x-axis =52

enter the obstacle in y-axis =44

Now for double robot single destination.

CRITICAL POS-1

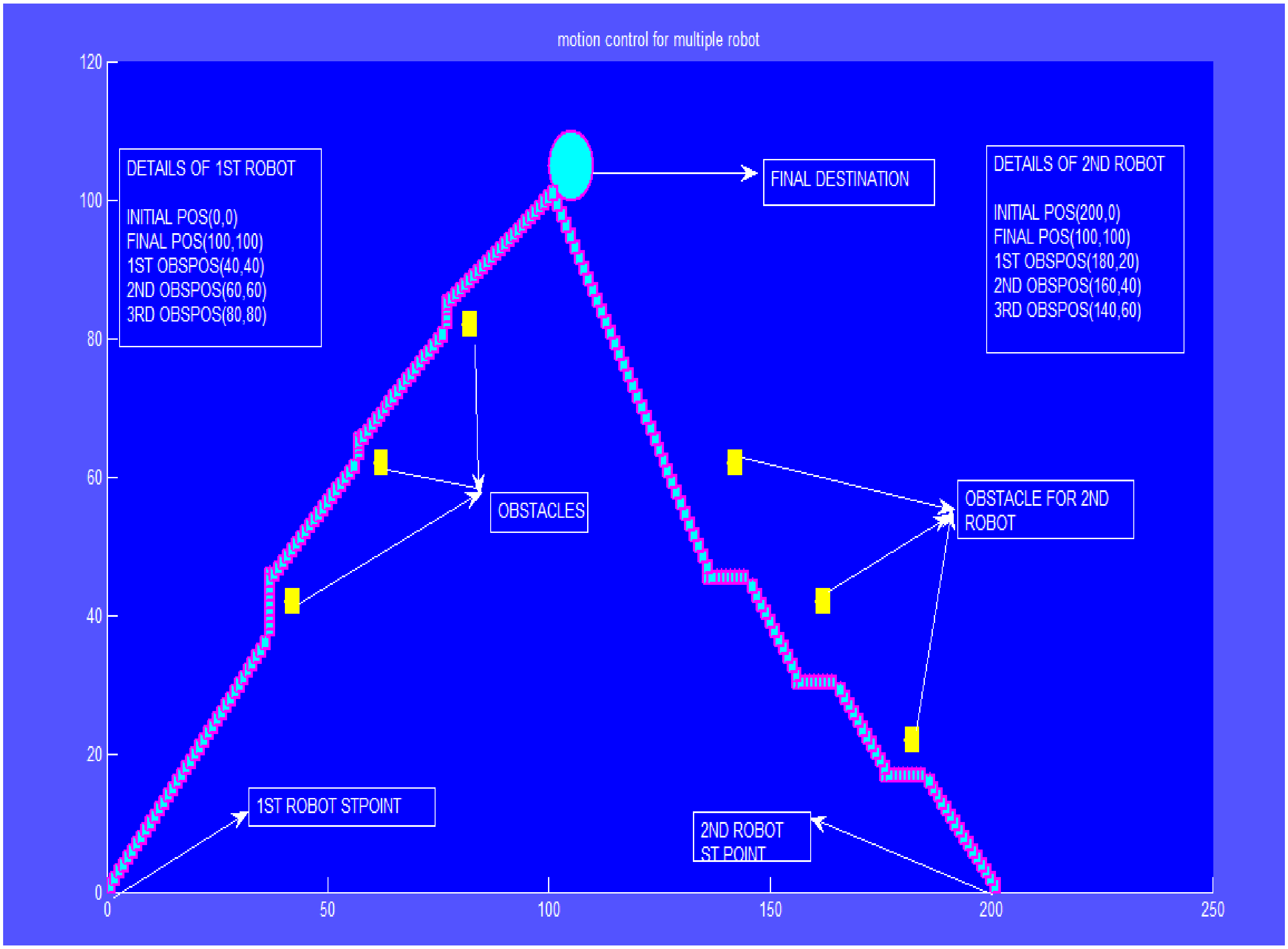


Fig 15- Obstacle avoidance for double robot and single destination case1

enter the target co-rdinate in x-axis =100

enter the target co-ordinate in y-axis =100

enter the obstacle in x-axis =40

enter the obstacle in y-axis =40

enter the obstacle in x-axis =60

enter the obstacle in y-axis =60

enter the obstacle in x-axis =80

enter the obstacle in y-axis =80

enter the target co-rdinate in x-axis =100

enter the target co-ordinate in y-axis =100

enter the obstacle in x-axis =180

enter the obstacle in y-axis =20

enter the obstacle in x-axis =160

enter the obstacle in y-axis =40

enter the obstacle in x-axis =140

enter the obstacle in y-axis =60

CRITICAL POS-2

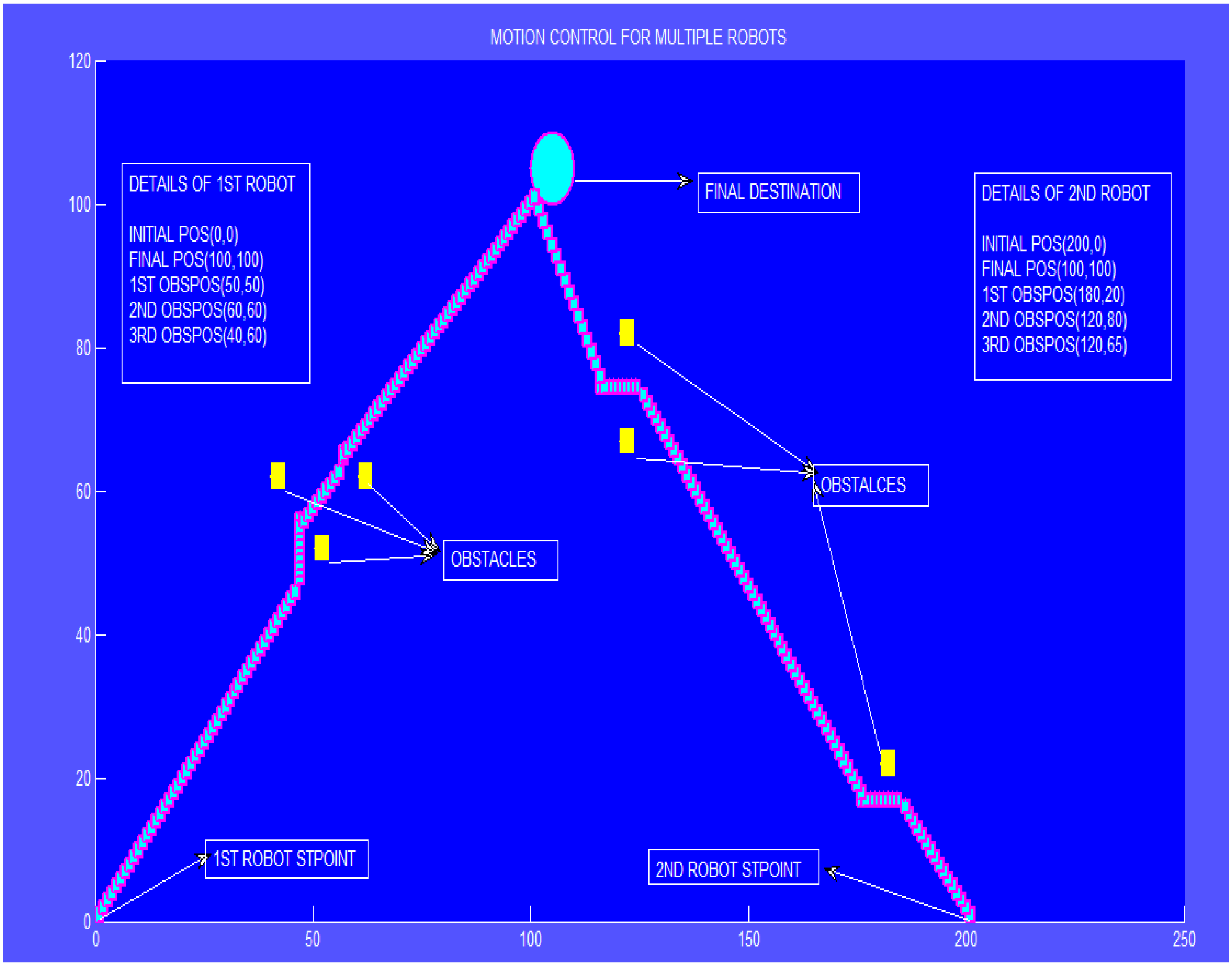


Fig 16- Obstacle avoidance for double robot and single destination case2

enter the target co-rdinate in x-axis =100

enter the target co-ordinate in y-axis =100

enter the obstacle in x-axis =50

enter the obstacle in y-axis =50

enter the obstacle in x-axis =60

enter the obstacle in y-axis =60

enter the obstacle in x-axis =40

enter the obstacle in y-axis =60

enter the target co-rdinate in x-axis =100

enter the target co-ordinate in y-axis =100

enter the obstacle in x-axis =180

enter the obstacle in y-axis =20

enter the obstacle in x-axis =120

enter the obstacle in y-axis =80

enter the obstacle in x-axis =120

enter the obstacle in y-axis =65

Obstacle avoidance for double robot and double destination.

CRITICAL POS-1

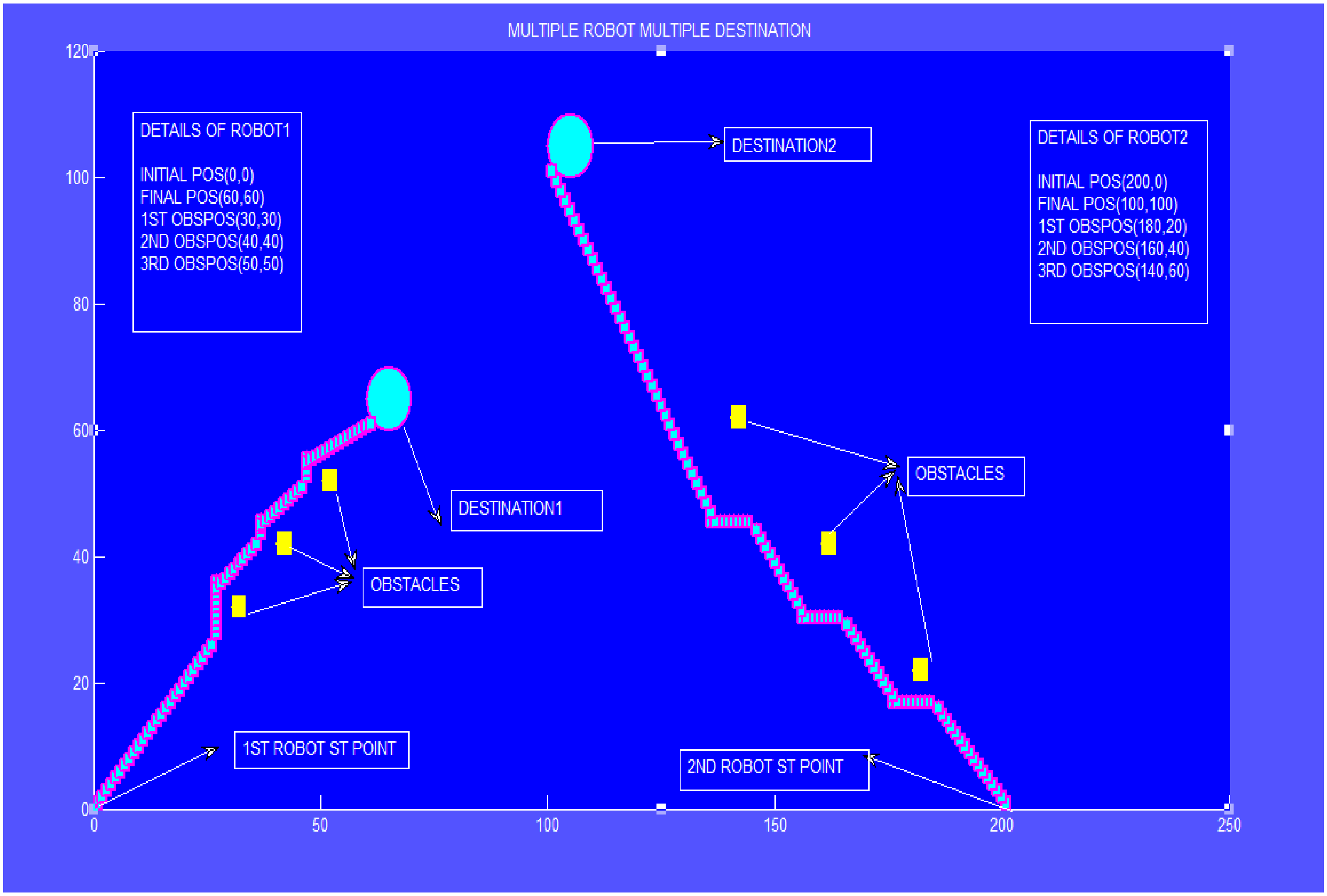


Fig 17-Obstacle avoidance for double robot and double destination case1

enter the target co-rdinate in x-axis =60

enter the target co-ordinate in y-axis =60

enter the obstacle in x-axis =30

enter the obstacle in y-axis =30

enter the obstacle in x-axis =40

enter the obstacle in y-axis =40

enter the obstacle in x-axis =50

enter the obstacle in y-axis =50

enter the target co-rdinate in x-axis =100

enter the target co-ordinate in y-axis =100

enter the obstacle in x-axis =180

enter the obstacle in y-axis =20

enter the obstacle in x-axis =160

enter the obstacle in y-axis =40

enter the obstacle in x-axis =140

enter the obstacle in y-axis =60

CRITICAL POS-2

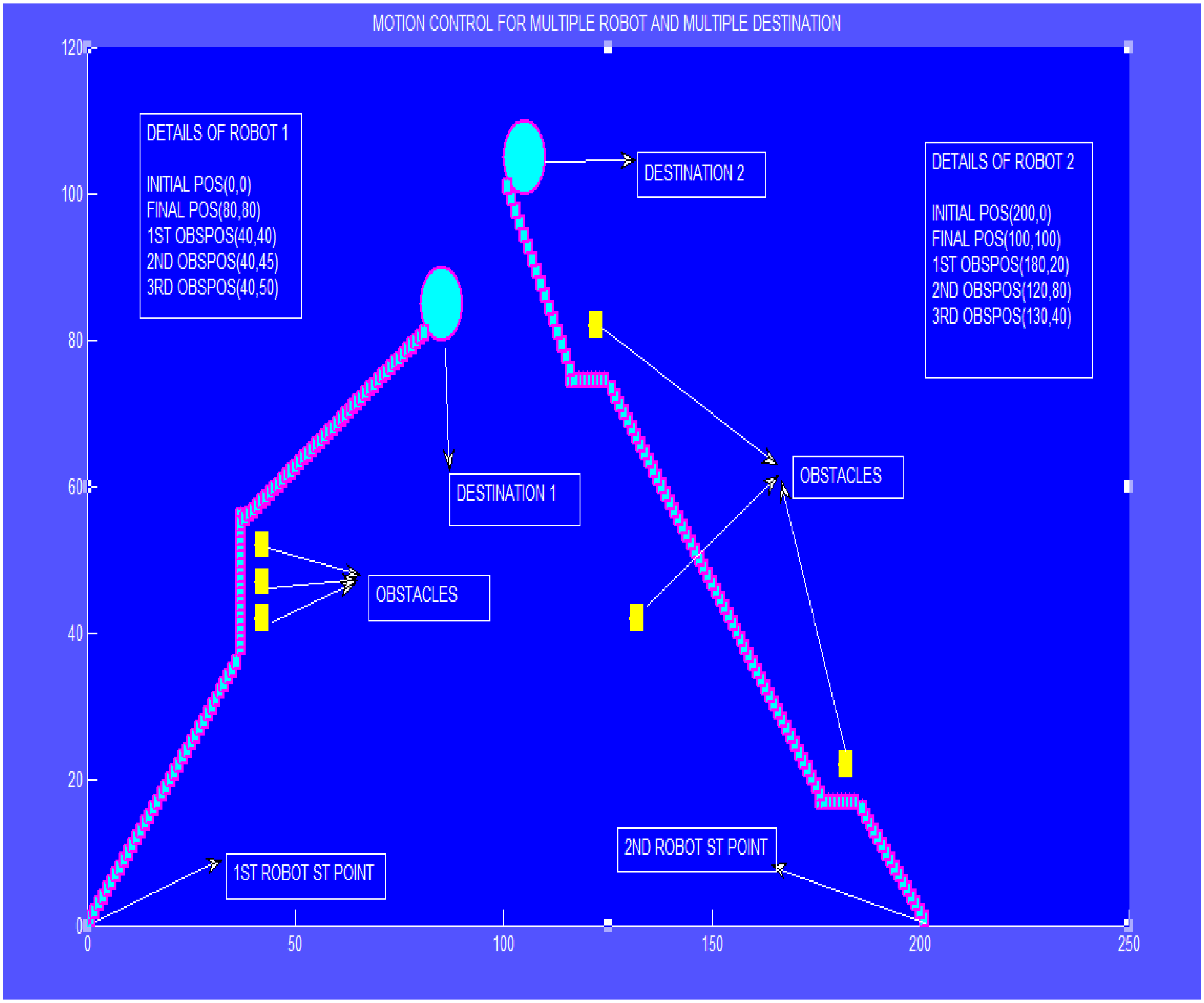


Fig 18 - Obstacle avoidance for double robot and double destination case2.

enter the target co-rdinate in x-axis =80

enter the target co-ordinate in y-axis =80

enter the obstacle in x-axis =40

enter the obstacle in y-axis =45

enter the obstacle in x-axis =40

enter the obstacle in y-axis =40

enter the obstacle in x-axis =50

enter the obstacle in y-axis =80

enter the target co-rdinate in x-axis =100

enter the target co-ordinate in y-axis =100

enter the obstacle in x-axis =180

enter the obstacle in y-axis =20

enter the obstacle in x-axis =120

enter the obstacle in y-axis =80

enter the obstacle in x-axis =130

enter the obstacle in y-axis =40

DISCUSSION

The navigation of the mobile is done with at most care. The navigation algorithm which is design for mobile robot navigation is found to be most efficient , reliable and real, it is working well for both the planned and unplanned situations, so it is of great important to the robotics. Further to show the effectiveness and reliability, simulation results are shown for different situations.

The obstacle avoidance activated when we encounter an obstacle that is less than the minimum threshold value set for obstacle avoidance. And when it detect any obstacle it change its trajectory, which is shown very vividly in obstacle avoidance section. There was not a single point where the robot becomes failed because of some malfunctioning in the algorithm. All the results are in accordance with our expectations this further proves there is not any single iota of mistake in algorithm part.

SCOPE FOR FURTHER WORK

There are lot of scope for future work in robotics, till now we have worked on the algoritm part, we have develop an fuzzy logic control system in fuzzy interface and algoritm for navigation and obstacle avoidane,which are two major contribution in the paper. But the major part become remain untouched, which is desigining a physical model and checking the simulation result of the programed one with the physical model. And lot of work can be done for navigation for multiple robot and multiple destination with a collision free path.

CONCLUSIONS:

From the above experimented observation, the following conclusions can be drawn.

1. With the help of a well-organized fuzzy logic control system the robot can easily identify both structured and unstructured environment and can reach the target with no difficulty this is shown in the result section.

2. A well-organized software is develop for many purposes like navigation of single robot single destination, double robot double destination.

3. Different kind of features like obstacle avoidance, speed control can be achieved using fuzzy logic control system. These are shown in different place in the report.

4. The fuzzy control system can be adopted in hazardous environments.

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